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Substation Structure Design Guide

Second Edition

Recommended Practice for Design and Use

Task Committee on Substation Structure Design

Edited by George T. Watson, P.E.

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Sponsored by
the Task Committee on Substation Structural Design of the
Electrical Transmission Structures Committee of the
Special Design Issues Technical Administrative Committee of the
Technical Activities Division of the
Structural Engineering Institute of the
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A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however, nor is it so elementary or so conclusive as to provides a "rule of thumb" for nonengineers.

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In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled "Manuals and Reports on Engineering Practice" to include the manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such manual or report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past manuals. Numbering would be consecutive and would be a continuation of present manual numbers. In some cases of joint committee reports, bypassing of journal publications may be authorized.

A list of available Manuals of Practice can be found at https://ascelibrary.org/page/books/s-mop.

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PREFACE

The Subcommittee on the Design of Substation Structures under the Committee on Electrical Transmission Structures from the Structural Engineering Institute of ASCE developed this Manual of Practice (MOP). The subcommittee membership represented utilities, manufacturers, consulting firms, and general interest. The combined expertise of the subcommittee members contributed to make this a valuable substation structure design guide for the utility industry.

The primary purpose of this MOP is to document electrical substation structural design practice and to provide guidance and recommendations for the design of outdoor electrical substation structures. This MOP covers a review of structure types and typical electrical equipment. Guidelines for analysis methods, structure loads, deflection criteria, member and connection design, structure testing, quality control, quality assurance, connections used in foundations, detailing, fabrication, construction, and maintenance issues are presented. This second edition also includes a chapter on foundation types used in substations. A chapter on retrofitting existing structures was included along with a chapter on oil containment and barrier walls. Appendix D is included as a draft prestandard to show what this MOP might look like if it were advanced to become a standard. In addition to Appendix D, Appendixes A, B, and C were added to cover various examples of structure design (Appendix A), a detailed explanation of short-circuit forces application to substation structures (Appendix B), and supplemental information on application of seismic forces as it applies to substation structures. The recommendations presented herein are based on the professional experience of the subcommittee members. Although the subject matter of this manual has been thoroughly researched, its application should be based on sound engineering judgment.

The subcommittee wishes to thank the peer review committee for their assistance and contributions to this document.

BLUE RIBBON PANEL REVIEWERS

The subcommittee wishes to thank the peer review committee for their assistance and contributions to this document.

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DEDICATION

Thomas A. Amundsen

This edition of the manual is dedicated to Thomas A. Amundsen. Tom provided 40 years of service to our industry and was instrumental in supporting, contributing, and mentoring this subcommittee's activities. His legacy lives on in this manual and with the engineers he developed, trained, and impacted over his life.

CHAPTER 1
INTRODUCTION

The purpose of this Manual of Practice (MOP) is to provide structural design guidance and a comprehensive resource for outdoor electrical substation structures and foundations. Engineers using this MOP may substitute or modify these recommendations on the basis of experience, research results, or test data. This MOP promotes the best utility practices for structural loads and design of electrical substation structures and acceptable electrical system performance. Electrical substations are an important component of the electrical system connecting the generation, overhead lines, and delivery points. The structure design loads provide an acceptably safe and reliable performance. This MOP uses the applicable ASCE 7-22 (ASCE 2022) wind, ice, and seismic loading in conjunction with overhead line tensions, and electrical clearances, as the basis of substation structure design. The application of these loads to substation structures is according to the procedures of this MOP.

The 113 committee has referenced many documents and included the specific year of publication where it was appropriate. As the various documents are revised, the reader should investigate what portion was changed and determine whether the changes impact the design of the substation structure. The term *latest edition* was avoided when referencing most documents.

Chapter 2, "Definitions, Electrical Equipment, and Structure Types," provides an overview of electrical equipment, identifies the various components and structure types, and describes structure configurations. With the exception of Chapter 11, "Retrofit of Existing Substation Infrastructure," the recommendations herein apply to new substation structures and foundations that support electrical equipment, rigid bus, and other conductors. Utilities should develop structure and foundation retrofit design criteria.

The electrical equipment supported by substation structures or foundations can be of significant weight, be subjected to substantial forces, and have attachments of porcelain or composite components. Guidelines for structural loads, deflection limits, analysis, design, foundations and anchorage, fabrication (quality assurance/quality control), maintenance, and construction of substation structures are presented. Oil containment and barrier walls are covered in Chapter 12, "Oil Containment and Barrier Walls." The structural loads and load combinations provided in this MOP can be regarded as minimum requirements. The selection of appropriate loads and load combinations for specific applications is the responsibility of the owner.

This MOP addresses steel, concrete, wood, aluminum, and porcelain or composite insulators used for the design of substation structures. Design equations are provided when references to existing structural design standards and codes (e.g., ACI, American Institute of Steel Construction, American Institute of Timber Construction, and ASCE) are not applicable.